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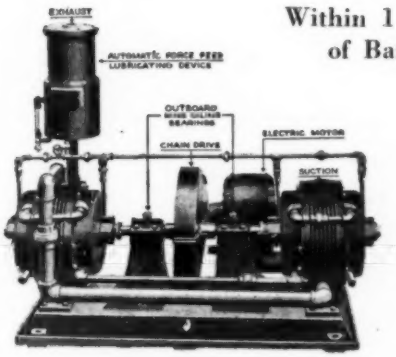


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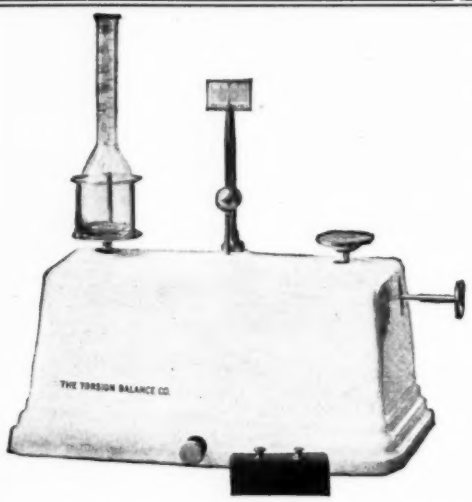


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OIL & FAT INDUSTRIES

VOLUME V MARCH, 1928 NUMBER 3

# Color Sensitivity

## Tests of Color Sense of A.O.C.S. Members and Data on Sensibility to Change in Lovibond Red*

BY IRWIN G. PRIEST†

### Abstract

THIS paper reports primarily upon tests of the color sense of about thirty men who have had large experience in the color grading of vegetable oils in terms of Lovibond glasses, nearly all of these men being members of the American Oil Chemists' Society. Similar tests on five other observers are also included for comparison.

All of the oil chemists were first tested by the Stilling Chart test, but the results by this test (although reported) are not the principal matter of interest. This test was regarded merely as preliminary, serving to discover any gross abnormality of color sense.

The tests of specific interest relate to the observer's ability to report correctly very small differences in Lovibond red at 35 yellow 7.6 red on the Lovibond scale, brightness differences being eliminated so that the judgment depends, in effect, entirely upon the observer's sensibility to difference in dominant wave length at equal brightness. The subject's ability in this regard was tested by the well known psycho-physical method of "right and wrong answers." The results for each observer are expressed so as to show the probability of his perceiving correctly given small differences in Lovibond red, under certain specified conditions.

The chief results may be summarized as follows:

1. A difference of 0.1 red at 35 yellow 7.6 red is perceived *with certainty* by only very few exceptional observers. However, this difference is perceptible in the sense that its presence does affect the observer's judgment *in the average*, although he is very doubtful of the reality of such a difference.

2. The perceptibility of a difference amounting to 0.27 red is notably higher; but even this difference is not perceived *with certainty* by all normal observers.

3. About two-thirds of the total number of oil chemists tested perceive a difference of 0.3 red at 35 yellow 7.6 red with practical certainty.

4. Although they have not been tested at the small difference of 0.1 red, it appears likely that about one-third of the chemists already tested could detect this difference with practical certainty if put to the test.

5. Four of the chemists tested appear to be unable to detect with certainty differences as great as 0.5 red. One proved to be very uncertain about differences as great as 10 units.

* Publication approved by the Director, Bureau of Standards, U. S. Department of Commerce. This report was presented orally at the meeting of the American Oil Chemists' Society in New York, October 28, 1927. Other aspects of these same data have been considered in a paper, "Preliminary Data on the Least Perceptible Difference in Dominant Wave Length . . . ," presented at the Twelfth Annual Meeting of the Optical Society of America, Schenectady, New York, October 20, 1927. See Proceedings in J. O. S. A. & R. S. I., vol. 16, p. 117; Feb., 1928.

† *Chief, Colorimetry Section, U. S. Bureau of Standards.*

*The author wishes to acknowledge the assistance rendered by his associate, Dr. Deane B Judd, in the preparation of this paper.*

It is emphasized that these results are to be regarded as preliminary, and the following recommendations are made:

1. The tests should be repeated in a more systematic way and under standard constant artificial daylight illumination, including the present observers and all other members of the Society who are engaged in the color grading of oils. For each observer the tests should be made for each of the following red differences in the order given: 0.5, 0.3, 0.2, 0.1.

2. When the data so obtained are available, the Society should, in the light of these data, set a standard of performance for those to be charged with the duty of color grading of oil.

Incidentally, these tests have shown that the normal observer's sensibility to difference in wave length is much greater than has been believed heretofore. Good observers can detect with certainty a difference of wave length as small as 0.1 millimicron for yellow light. This is of the order of one-fifth or one-tenth of what has been given as the "least perceptible difference" by previous authorities. This aspect of these data has been discussed in a paper communicated to the Optical Society of America at its meeting, October, 1927 (abstract to appear in the "Journal of the Optical Society of America," vol. 16, p. 117; February, 1928).

## Introduction

CHEMISTS dealing with vegetable oils are called upon to make the nicest discrimination of color in grading the oils. It is well known that many men in the general population are "color-blind," and that many others who may not be properly called "color-blind" do not have a strictly normal color sense nor the ability to perceive small differences in color. It seems obvious that the color grading of oils, which is a matter of paramount commercial importance, ought to be conducted by observers of proven ability in color discrimination. It developed, however, that very few, if any, of the men who have been engaged in this business for years had ever been adequately tested in this regard.

At the request of officers of the Society, I undertook certain tests of the color sense of members of the American Oil Chemists' Society at the annual meeting in Memphis, Tenn., May, 1927. This is the report upon these tests.

The purposes of this report are:

1. To give the members of the American Oil Chemists' Society an idea of the variations found among those who were tested, in order to afford a definite basis for considering the need of testing the color sense of those who are depended upon to grade the color of oil.

2. To give definite data upon the sensibility to change in red on the Lovibond scale[1] at 35 yellow 7.6 red.

In most cases the conclusions are to be regarded as indicative and tentative rather than definitive or final. In the case of most of the adverse findings, I do not believe that the tests at Memphis are *conclusive*. There are several reasons for this, e.g.:—(1) The circumstances of a convention are not the most favorable for a good score in such tests; (2) A low score on one day *may* be due to a merely temporary indisposition rather than to chronic abnormality; (3) The time available at Memphis was not adequate for an entirely satisfactory performance of these tests; (4) The test ought to be repeated with a constant standard artificial daylight illumination, after making certain improvements in apparatus and method.

## Description of Tests

The tests made were of two kinds, viz:

1. Ability to read the Stilling Charts.[2]

[1] Cf. B. S. Sci. Pap. 547, particularly p.11 and bibliography relating to the Lovibond system of color specification on p. 21.

[2] J. Stilling. Pseudo-isochromatische Tafeln. 14th Edition, Leipzig, 1913.

2. Ability to perceive small differences in red on the Lovibond scale at 35 yellow 7.6 red, differences in brilliance being eliminated so that the judgment was concerned only with differences in hue.[3]

Concerning the nature of the Stilling Chart test, the reader is referred to the publication just cited.

The tests of ability to perceive small differences in red at 35 yellow 7.6 red on the Lovibond scale were made with apparatus arranged as follows: A Martens photometer[4] was set with its axis horizontal so that the two halves of the field were uniformly illuminated by light from the north sky transmitted by a small plate of milk glass held in a vertical plane before the photometer. A 35 yellow glass and a 7.6 red glass were mounted together between the photometer and the observer's eye so that the observer looking into the instrument saw both halves of the field in the color due to this combination of glasses. Between the milk glass and the photometer was a holder in which could be inserted a Lovibond glass (hereafter known as the "difference glass") so as to cover either half of the photometer field as desired.[5]

The tests were conducted in a well lighted room in daylight so that the observer's eyes were light adapted; however, the photometer was provided with an eye shade to protect both of the eyes from disturbing side lights.

The tests were conducted substantially according to the following procedure:—The observer looked into the photometer and viewed the two-part field. He was instructed to match the brightness by adjustment of the photometer and observe that the two halves of the field were then exactly alike in color. A Lovibond red glass (the difference glass) adequate to produce a small but readily noticeable difference in hue was then introduced in front of the photometer so as to affect only one-half of the field, while a non-selective (neutral or so-called "colorless") glass was inserted on the other side. The observer again matched the brightness and observed the difference in hue. He was advised that, with this manner of observation, but with smaller differences in red, the test would consist in his reporting on which side the difference glass was inserted in each of ten separate trials in which he would be ignorant of its true position except in so far as he could tell from viewing the field. In other words, he knew that one side of the field was 35 yellow 7.6 red and the other, 35 yellow (7.6 + n) red, where n is some small fraction; and he was only required to indicate (by saying "right" or "left") in which side the "more red" appeared after he had matched the brightness. After each trial, while the observer looked away, the brightness match was disturbed by adjustment of the photometer (whether the difference glass was changed or not) so that he could not infer the position of the difference glass from the difference in brightness in the next trial. He was instructed to report his *slightest inclination* to one side

[3] The observers were accustomed in the general practice of oil color grading to the presence of a combination of both difference factors, i. e., of hue and brilliance.

[4] Martens. Physikalische Zeitschrift, 1. pp. 299-303; 1900.

[5] This holder consisted of a small black box with slots to hold the Lovibond glass. On one side of this box, a clamp served to attach it to the photometer, while the other side carried the above mentioned plate of milk glass. (See Fig. 1).

TABLE 1

GENERAL SUMMARY OF TESTS OF COLOR SENSE MADE FOR A.O.C.S.

AND COMPARISON WITH DATA FOR OTHER OBSERVERS.

(Small Letters in Parentheses in this Table refer to Notes on the Following Page.)

| Observer's Identification No. (a) | Class on Stilling Chart Test (b) | Perceptibility of Small Differences in Red at Lovibond 35Y 7.6R (c) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Red Diff. (Lovib. Units) | 0.093 | 0.16 | 0.27 | 0.41 | 0.53 | 1.00 | 1.22 |
| | | Δ A (d) (millimicrons) | 0.1 | 0.2 | 0.35 | 0.5 | 0.65 | 1.2 | 1.5 |
| OIL CHEMISTS | | Eye | | | | | | | |
| 1 | N+ | | (Not tested) | | | | | | |
| 2 | N | | (Record lost) | | | | | | |
| 3 | N+ | right | | 4 | 10 | | | | |
| 4 | N | left | | | 9 | | | | |
| 5 | N | left | | 7 | 10 | | | | |
| 6 | Q | left | | | 7.5(f) | 10 | | | |
| 7 | N | right | | 5 | 10 | | | | |
| 8 | N- | right | | | 9 | 10 | | | |
| 9 | N | right | | | 7 | 10 | | | |
| 10 | N | right | | 9 | 10 | | | | |
| 11 | N | right | | 9 | 9 | | | | |
| 12 | D | right | | | 8(g) | 4 | 8 | | |
| 13 | N+ | right | | 9 | 9 | | | | |
| 14 | Q | right | (May 25 | | 7 | | 8 | | 10 |
| 14 | | right | (May 26 | } (h) | 8 | | | | |
| 15 | N | left | | 10 | 10 | | | | |
| 16 | N+ | right | | 9 | 9 | | | | |
| 17 | N | left | | | 8 | | | | |
| 18 | N | right | | 8 | 9 | | | | |
| 19 | N | right | | 7 | 10 | | | | |
| 20 | N | left | | | 6 | 10 | | | |
| 20 | | left | | 7 | 9 | | | | |
| 21 | N | right | | 10 | 9 | | | | |
| 22 | N | right | | 4 | 10 | | | | |
| 23 | N- | right | | | 8 | | | | (i) |
| 24 | N | right | | | 4 | | 8(j) | | |
| 25 | N | right | | 6 | 9 | | | | |
| 26 | N | left | | 7 | 9 | | | | |
| 27 | N | left | | 8 | 9 | | | | |
| 27 | | right | (Without glasses) | | 9 | | | | |
| 27 | | right | (With glasses) | | 8 | | | | |
| 28 | N+ | right | | 9 | 10 | | | | |
| 29 | D?(e) | both | | | | | | 4(q) | (k) |
| 29 | | | | | | | | 9(r) | |
| 30 | N | | (Not tested) | | | | | | |
| 31 | N (e) | | (Not tested) | | | | | | |
| 32 | N (e) | | (Not tested) | | | | | | |
| Mean of all | | | | 7.5 | 8.5 | | | | |
| Mean of 17 also tested at red diff. 0.16 | | | | | 9.5 | | | | |
| Total number of observers | | | | 17 | 26 | | | | |
| Number scoring 10 (maximum possible) | | | | 2 | 8 | | | | |
| " " 9 or more | | | | 7 | 18 | | | | |
| " " less than 9 | | | | 10 | 8 | | | | |
| " " more than 8 | | | | 14 | 25 | | | | |
| Minimum score | | | | 4 | 4 | | | | |
| Number making only minimum score | | | | 2 | 1 | | | | |
| OTHER OBSERVERS (Approximately Normal Trichromats) | | | | | | | | | |
| D. B. Judd (l) | | right | 10 | 10 | | | | | |
| K. S. Gibson (m) | | left | 7.4 | 8.2 | | | | | |
| C. K. Walker (n) | | right | 8 | 10 | | | | | |
| J. O. Riley (o) | | right | 7 | | | | | | |
| M. L. Brown (p) | | left | 8 | 9.5 | 9.5 | | | | |

The values given in this part of the table, for observers other than the oil chemists, are estimated from more extensive data which are shown in detail in Table 2.

or the other even though he was very doubtful of the correctness of the answer. It was emphasized to him that a small (even if hardly perceptible) difference was actually present, and it was up to him to make his "best bet" on it. He was further advised that if he insisted upon saying "matched" (no difference) instead of "right" or "left," his answers so made would be arbitrarily divided into equal numbers of "correct" and "incorrect" in computing his score. Thus, the result would depend entirely upon chance quite unassisted by his vision. The purpose of this rule was to force the observer to disclose the

NOTES TO TABLE 1

(As indicated by Letters in Table)

(a) Oil chemists, men who are experienced in color grading oils in terms of Lovibond glasses. (Nearly all are members of A. O. C. S.). Except as noted, tests were made at the Memphis Convention, May, 1927.

(b) The symbols in this column have the following meanings:

N means normal. (N + means that the observer read the charts with unusual ease and accuracy. N — means that the observer had some difficulty in reading the charts, as shown by his hesitation.)

Q means that, although the observer can not be definitely classed as decidedly abnormal, he experienced so much difficulty in reading that one does not feel justified in classing him without qualification with those who read with much greater ease.

D means definitely defective in color discrimination.

D! means undoubtedly abnormal to a marked degree.

(c) The numbers in the columns headed by differences in red (0.093, 0.16, 0.27, etc.) are the number of times that the observer reported the difference *correctly* in 10 trials. Blank spaces indicate that no test was made for that difference.

(d) $\Delta \Lambda$ is the difference in dominant wavelength (in millimicrons) corresponding to the difference in Lovibond red given in the column heading.

(e) Tests made at the Bureau of Standards, Washington.

(f) Saw "no difference" 5 times out of 10.

(g) After practice on the larger differences, 0.41 and 0.53.

(h) These tests were made rather late in the afternoon (about 5 P. M.). The illumination was not as high as desirable. This observer might do better in the morning or with a higher illumination.

(i) Incomplete test. Observer answered correctly 4 times in 4 trials for difference of 1.22 R.

(j) Observer very slow in making answers.

(k) This observer is an anomalous trichromat (protanomaly), quite incompetent to make accurate color matches. He proved to be uncertain about differences as great as 10 units of Lovibond red!

(l) Dr. Judd is Associate Physicist in the Colorimetry Section of the Bureau of Standards. He has had a large experience in making color matches with great care.

(m) Dr. Gibson is Physicist in the Colorimetry Section of the Bureau of Standards. He has had much experience in colorimetry and photometry. N. B.—See footnote 6 in text.

(n) Miss Geraldine K. Walker is now Research Associate of the American Oil Chemists' Society, in the Colorimetry Section of the Bureau of Standards. These tests were made when she applied for this position. She had had previous experience in colorimetry at the Munsell Research Laboratory, but had never seen a Lovibond glass before these tests were made. The consistency of her current work in grading the glasses indicates that she would make a still better score in this test at the present time. (November, 1927).

(o) Mr. Riley is Aid in the Colorimentry Section of the Bureau of Standards. He had had some experience (not very great) in color matching before these tests were made.

(p) Miss Mabel E. Brown, as Assistant to Mr. Carl W. Keuffel in spectrophotometric work with Keuffel and Esser, had had a great deal of experience in photometry and spectrophotometry, but not so much in other color matching. She had never worked with the Lovibond glasses prior to this test.

(q) First trial.

(r) Second trial after practice with larger differences.

very smallest differences he suspected even if he was quite doubtful of their reality. It was made plain to him that he had "everything to gain and nothing to lose" by reporting his slightest suspicions as to the difference in color. Proceeding in this manner the conductor of the experiment placed the difference glass 5 times to affect the left field and 5 times to affect the right field, the observer being ignorant of the order in which this was done.[6]

[6] The usual order, with very few exceptions was: (1) left, (2) right, (3) right, (4) left, (5) left, (6) right, (7) right, (8) left, (9) left, (10) right.

The procedure, instructions, and advice to the observer were not always *literally* as just outlined. In practice it becomes almost impossible to treat every observer *exactly* alike.

### Results of the Tests

The results of the tests are presented in Table 1 which shows the number of correct answers in ten trials for the several differences used in making the tests. In considering these results the following remarks should be noted:

1. Owing to lack of time the data are not as complete as could be desired. Each observer should be tested a number of times at each of several differences beginning with larger and working to smaller differences until the difference becomes so small that the observer's answers indicate his inability to perceive it.

2. The score 10 indicates that the difference in question was perceived with practical certainty. (The observer can report it correctly, *provided he trust his vision i.e., provided he answer in accord with his slightest suspicion of difference even if very doubtful.*)

3. Of course, even one incorrect answer in the 10 trials shows that the observer is somewhat less than "certain" about the difference. On the other hand we have no guarantee that he would answer correctly 100 times in 100 simply because he answered correctly 10 times in 10. It is, however, not likely that he would answer correctly much less than 90 times in 100. In comparing different individuals on the basis of only 10 trials we are hardly justified in distinguishing between those who score 9 and those who score 10. In default of more extensive data, we may say that a score of 9 or 10 indicates "practical certainty."

4. The score 5 indicates that he can perceive the difference just as well as a blind man. In other words, by flipping coins or throwing dice, he should get the correct answer about 5 times out of 10 without looking into the color comparator. (Cf. results for zero red difference in Table 2 and in footnote 6.)

TABLE 2

| Lovibond Red Difference | Fraction Answered Correctly | Fraction Answered "Left" | Clock Time: Start of Test | Clock Time: End of Test | Elapsed Time in Minutes |
|---|---|---|---|---|---|
| 0.495 | 1.00 | 0.50 | 11:16 a.m. | 11:20 a.m. | 4 |
| 0.296 | 1.00 | 0.50 | 11:26 | 11:30 | 4 |
| 0.185 | 0.85 | 0.65 | 11:31 | 11:46 | 15 |
| 0.104 | 0.80 | 0.60 | 11:49 | 12:13 p.m. | 24 |
| 0.000 | 0.35 | 0.45 | 12:16 p.m. | 12:32 | 16 |

The following particulars concerning these tests of December 27 should also be noted:

(1) The order of presentation was *not* that given in the beginning of this footnote, but was in each case determined by chance, subject to the condition that the number of presentations on the left equal the number on the right.

(2) The observer says he felt no greater difficulty in making decisions for the zero difference than for the difference 0.104. He was not aware that the test was being made for zero difference but supposed that a very small difference (less than he could perceive with certainty) was being used in the test.

(3) The "elapsed time" in making the answers is significant as indicating the observer's greater hesitation in deciding for the smaller differences.

(This footnote will be better understood after reading the next section of the paper on "Results of the Tests.")

It is believed, however, that the procedure actually followed in all cases was such as to lead to the same results as would be found by the procedure that has been described.

Only two observers (No. 6 at Memphis and Dr. Gibson in Washington) have insisted on reporting "matched" in some cases. On reading the MS of this paper, Dr. Gibson states that, according to his memory, the tests in his case (Tables 1 and 2) were *not* governed by the instructions outlined here. In particular, he says, his reports were *not* based on *a priori* knowledge that the difference glass was actually in all cases on one side or the other but were, in effect, based on the assumption that it might be on *neither* side, in which case "matched" would be a legitimate answer. It should also be recalled that nearly all observers actually are strongly inclined to report "matched" for differences less than 0.3R; and would readily do so in many cases if not required to report "right" or "left." However, a careful repetition of the tests, December 27, 1927, without allowing the answer "matched" to be made, gives results for Dr. Gibson in complete accord with the "Fictional Fraction Correct" given for him in the last column of Table 2. The results of these new tests (December 27, 1927), the determination for each difference being based on 20 trials, are as follows:

TABLE 2

SENSIBILITY TO CHANGE IN RED AT LOVIBOND 35 YELLOW 7.6 RED

SUMMARY OF ALL TESTS AT THE BUREAU OF STANDARDS, MAY 11 TO OCTOBER 8, 1927.

| Observer | Date | Difference in Lovibond Red Units | Difference in Dominant Wave Length | Total No. of Trials in one set of Answers | Number of Correct Answers C | Number of Incorrect Answers I | Number called "Match" M | Fraction Correct: Literal $\frac{C}{C+I+M}$ | Fraction Correct: Fictional $\frac{C+\frac{1}{2}M}{C+I+M}$ |
|---|---|---|---|---|---|---|---|---|---|
| D.B.Judd | 5-11-27 | 0.16 | 0.2mμ | 20 | 20 | 0 | 0 | 1.00 | 1.00 |
| | 5-11-27 | .093 | .1 | 20 | 20 | 0 | 0 | 1.00 | 1.00 |
| | 9- 9-27 | .093 | .1 | 20 | 20 | 0 | 0 | 1.00 | 1.00 |
| | 5-13-27 | ZERO * | 0.00 | 20 | 9 | 11 | 0 | 0.45 | 0.45 |
| K.S.Gibson (N.B.- See footnote 6 in text) | 5-11-27 | 0.16 | 0.2 | 20 | 14 | 1 | 5 | 0.70 | 0.82 |
| | 5-11-27 | .093 | .1 | 20 | 10 | 2 | 8 | .50 | .70 |
| | 9- 9-27 | .093 | .1 | 20 | 14 | 3 | 3 | .70 | .78 |
| G.K.Walker | 8-26-27 | 0.17 | 0.2 | 10 | 10 | 0 | 0 | 1.0 | 1.0 |
| | 8-26-27 | .104 | .1 | 10 | 7 | 3 | 0 | .7 | .7 |
| | 8-26-27 | .093 | .1 | 10 | 9 | 1 | 0 | .9 | .9 |
| M.E.Brown | 10- 8-27 | 0.28 | 0.35 | 20 | 19 | 1 | 0 | 0.95 | 0.95 |
| | 10- 8-27 | .15 | .2 | 20 | 19 | 1 | 0 | .95 | .95 |
| | 10- 8-27 | .104 | .1 | 20 | 17 | 3 | 0 | .85 | .85 |
| | 10- 8-27 | ZERO * | 0.00 | 20 | 7 | 13 | 0 | .35 | .35 |
| J.O.Riley | 9- 9-27 | 0.093 | 0.1 | 20 | 14 | 6 | 0 | .7 | .7 |

* The meaning of "ZERO" here is as follows: The test being conducted just as in other cases, a neutral glass (non-selective crown) is surreptitiously substituted for the fractional Lovibond glass. The observer imagines he is responding to small differences as in the bona fide experiments. The most probable value for $(C+\frac{1}{2}M)/(C+I+M)$ in these circumstances is 0.5. Of course, it is not to be expected that this value will be obtained every time in such an experiment. Indeed, the probability of obtaining exactly 0.5 in 10 trials is only 0.24 and in 20 trials, only 0.18. However, the probability that $(C+\frac{1}{2}M)/(C+I+M)$ will lie between 0.3 and 0.7 inclusive, for 20 trials, is 0.96.

*Fig.* 1. *Testing the Ability to Perceive Small Differences in Lovibond Red*

*The observer, looking into the Martens photometer, sees a circular field divided by a vertical diameter. Both halves of the field are illuminated by daylight transmitted by the milk glass, the two halves being illuminated respectively by different parts of the milk glass. The Lovibond combination 35Y 7.6R, being placed permanently between the observer's eye and the photometer, determines the color of both halves of the field. The difference glass (e.g. 0.1R, 0.2R, or 0.3R) is inserted between the milk glass and the photometer by the conductor of the experiment so as to affect the color of one half only, which may be either the right or the left at the option of the conductor of the experiment. In any one set of answers the difference glass is actually placed on the right as many times as on the left, but in an order unknown to the observer. The observer has no means of knowing on which side it has been placed except by his ability to perceive hue differences. He matches brilliance (by turning the circle, C, which rotates the nicol prism of the Martens photometer) and indicates the side on which he believes the difference glass to be, by saying "right" or "left." The conductor keeps a score of correct and incorrect answers.*

5. Any score above 5 *indicates* that *probably* the observer's color sense had *something* to do with determining his answers, but obviously a score of 6 is, in practice, not of great significance. With "good luck" a blind man *might* guess right 6 times out of 10. His most probable score is 5, but his chance of scoring 4 or 6 is almost as great. (See tabular values just below.) However, the blind man's chance to guess correctly 10 times out of 10 is less than 1 in 1000. The significance of the scores in general is best made clear by considering the "blind man's chance" of making them, i.e., the probability of obtaining these scores by pure chance without the aid of the color sense. These probabilities are *approximately* as follows:

| Score | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Probability of score | 1/1000 | 1/100 | 4/100 | 12/100 | 20/100 | 25/100 | 20/100 | 12/100 | 4/100 | 1/100 | 1/1000 |

The probability that the "blind man's score" be 4, 5, or 6 is 66/100 and the probability that it be 3, 4, 5, 6, or 7 is 89/100. The probability that it be more than 5 is about 38/100. The probability that it be more than 6 is about 16/100. The probability that it be more than 7 is only about 5/100; more than 8, 1/100. The observer who has answered correctly 10 times in 10 trials has done something which can be expected by chance only about once in a thousand times. If he repeats this performance (i.e., answers correctly 20 times in a total of 20 trials) he has done something which can be expected by chance only about once in 1,000,000 times.

6. For purposes of comparison, there is subjoined to Table 1 data on other normal observers obtained at the Bureau of Standards; and these data are shown in detail in Table 2.

Before beginning the tests the observer was first coached by telling him the true position so as to fix his criterion for the difference to be observed. Also, coaching and practice intervened between successive trials as indicated in the table. The observer was very hesitant in deciding, but never answered "matched." He was most confident of the correctness of some of the wrong answers. He also expressed the opinion that his sensibility was changing during the experiment. It appears from these data that the difference in Lovibond red at 35 yellow 7.6 red must be more than 3 units in order to be perceived with certainty by this observer, when the brightness difference has been eliminated.

This observer is not an oil chemist and not engaged in the use of Lovibond glasses; but the data are important as showing the uncertainty of Lovibond matches by an

TABLE 3

| Hour A.M. | Difference in Lovibond Red Units | Total Number of Trials | Number of Correct Answers | Number of Incorrect Answers | Number Called "Match" | Fraction Correct |
|---|---|---|---|---|---|---|
| 9:15 | 1.2 | 20 | 14 | 6 | 0 | 0.70 |
| (Coaching and practice intervened) | | | | | | |
| 9:30 | 1.2 | 20 | 16 | 4 | 0 | 0.80 |
| (More coaching and practice) | | | | | | |
| 9:40 | 3.1 | 20 | 19 | 1 | 0 | 0.95 |
| (More coaching and practice) | | | | | | |
| 10:00 | 1.2 | 20 | 15 | 5 | 0 | 0.75 |

7. Data on an anomalous trichromat of the extreme deuteranomalous type are shown in Table 3. These data were obtained at the Bureau of Standards, May 13, 1927 in the same way as the data shown in Table 2.

observer of this type. One of the oil chemists (No. 29) is also an anomalous trichromat, but of the protanomalous type.

## Conclusions

The following conclusions are

drawn from the data presented above.

1. A difference of 0.1 R at 35Y 7.6R (about 0.1 millimicron in dominant wave length) is perceived *with certainty* by only very few exceptional observers. Of all our observers, only one (D. B. Judd, Bureau of Standards) so far has a perfect score in reporting this difference correctly. He has reported it correctly 20 times out of 20 in *each of two* sets of 20 trials. (The chance of such a performance by accident is less than one in a million million.) None of the oil chemists was tested at this small difference. However, of 17 who were tested at a difference of 0.16 R, only 2 made perfect scores; and, of 26 who were tested at a difference of 0.27 R, only 8 made perfect scores.

Nevertheless, the difference of 0.1 R is perceptible in the sense that it *does* affect the result *in the average*. If this difference had no effect in determining the observer's answers, then in a large number of answers we should expect about an even division between correct and incorrect. In dealing with a number of observers, we should expect about as many to score below 50% correct as above 50% correct. Consider the data in Table 2 from this point of view. For the difference of *about* 0.1 R we have seven cases on the basis of 20 answers in one set.[7] Note that in each and every case the percentage of correct answers is not merely greater than 50 but is indeed greater than 60; and, with only one exception, greater than 70. The chance of the percentage of correct answers being greater than 60 in *one* such case "by accident" is about 13 in 100 (or, more accurately, 0.1316). The chance of it being greater than 60 in all of the seven cases is[8] less than 7 in 10,000,000. Since, in some of these cases, the percentage correct is still greater, the chance of the answers occurring by accident as they actually did occur is even less than these computations indicate. In the ordinary usage of language and in so far as it is usual or useful to make a distinction between doubt and certainty, this is equivalent to saying that it is "*certain*" that this distribution of answers is not due to chance. The trials with "zero" difference in red (Cf. Table 2 and particularly the note to that table) show that the percentage of correct answers is in fact a fair approximation to what would be expected to result from chance distribution according to the theory of probability assuming the answer "left" to be just as probable as the answer "right," in each trial. Consequently, it appears certain that the wide departure from chance distribution which occurs when the 0.1 R glass is substituted for the zero glass (all other conditions remaining the same) must be due to the color difference occasioned by the 0.1 R glass.

2. For a difference of 0.27 R (about 0.33 millimicron in dominant wave length), we find the perceptibility notably higher. Eight out of 26 oil chemists tested answered correctly 10 times in 10 trials (See Column 6 of Table 1). Eighteen scored 9 or 10; that is, they perceived the difference with practical certainty. Only one scored less than 6. In a total of 30 tests (on 26 observers) only one score was less than 6. The significance of these results as indicating the

[7] Two sets each for Judd and Gibson and one set each for Riley, Brown, and Walker, considering Miss Walker's two sets of ten as one set of 20 for convenience in computing.

[8] Computed as $(0.1316)^7$.

perceptibility of this difference is emphasized by considering the following probabilities. The chance of each and every one of 8 separate scores being 10 by accident is much less than 1 in $10^{24}$. The chance of each and every one of 18 separate scores being 9 or 10 by accident is less than 4 in $10^{30}$. The chance of each and every one of 29 separate scores being more than 5 is but little more than 5 in $10^{15}$. The evidence that this difference (0.27R) is perceptible in the sense that its presence affects the answers to a notable extent is overwhelming. On the other hand, it must be admitted that there are many individuals to whom it is not perceptible *with certainty*; moreover we would not be justified in classing these individuals as abnormal.

3. A selected group of about 19 of the men tested at Memphis perceive a difference of 0.3 R with practical certainty.[9]

4. Although they have not actually been tested at a difference of 0.1 R, it appears likely (from the other tests) that about one third of the oil chemists already tested could detect with practical certainty[10] a red difference as small as 0.1 R at 35 yellow 7.6 red.

5. Four of the oil chemists tested appear to be unable to distinguish with certainty differences as great as 0.5 R at 35 yellow 7.6 red, and one (No. 29) is uncertain about differences as great as 10 units.[11]

[9] That is, their scores are 9 or 10 in this test.

[10] That is, by the test here described, would score 9 or 10.

[11] This observer states that he is not actively engaged in color grading oils, and has not been concerned with this work for some years past.

### Individual Reports

For obvious reasons individuals among the oil chemists have been designated only by number in this report.

Each individual tested will be privately advised of *his own* score in the tests reported in this paper, but obviously *the author is not willing to communicate the results for named individuals to others than the person to whom they refer. All persons are requested to refrain from asking for the scores of others than themselves.*

### Recommendations

In the light of the experience and preliminary data gained in these experiments the following recommendations are made:

1. The tests should be repeated in a more systematic way and under standard constant artificial daylight illumination, including the present observers and all other members of the Society who are engaged in color grading oils. For each observer, the tests should be made for each of the following red differences in the order given: 0.5, 0.3, 0.2, 0.1.

2. When the data so obtained are available, it is suggested that the Society should, in the light of these data, set a standard of performance for those to be charged with the duty of color grading oil.

*Bureau of Standards, Washington, May-December* 1927.

*Revised, March* 5, 1928.

# The Fish Oil Industries

## Describing the Production and Utilization of Fish and Marine Animal Oils

BY FREDERICK H. MEISNEST

(*Continued from February issue*)

### Sardine Oil *(Cont.)*

It is possible to ship the oil direct to the consumer in tank cars from the California reduction plants since almost all such plants have railroad siding facilities for shipping the canned product. This is practically the only place in the United States in the fish oil industry where it is possible to ship the oil without transporting it first to shipping centers.

Part of the production in California is consumed locally by paint dealers but the bulk is shipped East for use in soap. In 1925 and 1926 some was used (about 700,000 pounds) for lard compound. Of the 15,000 tons of fish meal the bulk is used locally for animal food and for fertilizer. The exportable surplus is shipped mainly to Japan.

### Pilchard Oil

In 1925 the Canadian government by an Order in Council permitted the use of pilchards for reduction purposes in Canada. Later they permitted the use of herring in certain districts. During the first season one machinery company sold six plants that were installed on the west coast of Vancouver Island, which is the only place in Canada where pilchards are taken.

The pilchard was first noticed by the herring fishermen when they appeared in large quantities in 1918. It is a California sardine that has migrated north, and scientifically it is a sardine. However the oil is imported into the United States as herring oil.

Since 1925 about twenty-five plants have been installed.

The Canadian pilchard yields more oil than the California sardine and I have seen them average 50 to 75 gallons of oil per ton of fish. In California they average only about 35 gallons per ton.

A few salmon canneries have canned the pilchard but apparently they have not made much money or else they would not have requested the government to permit their use for reduction purposes. The extent of the pilchard resources are not accurately known, but from my personal experience I think they are capable of supporting a large industry, and a steady supply will be available although the runs will be sporadic. The coast line from Barclay Sound to Quatsine Sound is rugged and the pilchard schools enter the numerous bays for food or else for shelter. As the fishermen study the runs they may also discover where the schools are when they are not in the bays and consequently the production may be increased. Its progress may be as startling as the sardine oil production of Madras, India has been. In 1915 it was very small and now large quantities of oil are produced. This is indeed remarkable since the 600

*Interior view of large sardine canning plant*

producing plants use antiquated methods.

The methods employed in the Canadian pilchard industry are similar to those used in the California sardine industry. However, during the past season some reduction plants have been installed of the same type as used in manufacturing menhaden oil. This type of plant I consider wasteful and inefficient. There is an opportunity for some individual to develop a system which will be more efficient and supplant those now in use. The plants in use now leave from 5 to 12% oil in the meal and take from 5 to 8 tons of fish to make one ton of meal, whereas an efficient plant should produce one ton of meal from four tons of fish. Since oil is worth about 6¼c per pound and meal worth only 3c per pound this extra 5 to 12% oil should be recovered.

The plants in use lose large quantities of nitrogenous material and albuminoids by using the wet rendering method. They use this type of plant because they are in use elsewhere and because they will not experiment with a new type. I have examined the products of these plants and found that the emulsion of oil and water contains 25% solids.

Canadian pilchard oil is produced from April to December and some operators are experimenting with new fishing methods in hopes of being able to fish the year around.

Only small quantities of the oil are consumed in Canada, over 50% is exported to the United States for use principally in soap. The balance is exported to Europe.

The Canadian oil sells for approximately the same price as Alaska herring oil. (The United States tariff is 5c per gallon.)

### Herring Oil

Herring oil is manufactured in Alaska and in Maine. The Maine industry is conducted as a by-product of the sardine industry and the production is only about 1,000,000 pounds a year while the Alaska production is about 20,000,000 pounds per year.

In Alaska a reduction plant is an essential adjunct to a herring saltery because it has a large amount of waste available. In central and westward Alaska the salting of the fish is the major industry since about 90% of the fish are very large. In the important southeastern district 85% of the fish are small so that the manufacture of meal and oil is the principal industry and salt herring is a minor product. In 1926 about 85% of the total of Alaskan herring oil was produced in Southeast Alaska.

The herring strike in at Cape Commansy in June and continue to run until October. These are pelagic fish that live in the open ocean and enter the bays at certain times of the year. I believe that it will be hard to deplete the supply of fish permanently though it might be possible that intensive fishing would decrease the catch for a number of years.

The methods used in manufacturing herring oil are typified by the following description of a large plant. This company employs 3 purse seine boats to catch its supply of fish and operates a saltery in conjunction with the manufacture of meal and oil. Like the other reduction plants it is a complete settlement by itself. It has a suit-

*Automatic machines for filling sardine cans with oil. Thousands of barrels of cottonseed and other oils are used annually in packing sardines*

*"Kildonan," an up-to-date cannery on the west coast of Vancouver Island*

able harbor, adequate water supply, and storage and warehouse facilities.

The reduction plant is of the continuous type and like the fifty other plants in Alaska is as automatic as it is possible to make it. It has conveyors and elevators to carry the fish instead of manual labor as used in the menhaden industy. The fish are cooked, pressed and dried in equipment similar to that of the sardine industry.

With infrequent steamer service it is necessary to have large storage capacity and like all fishermen the men are optimists, for they believe in having capacity to store their largest catches, and warehouse facilities for storing large quantities of meal.

These plants in Alaska are over a thousand miles from Seattle and have steamer service about every ten days. The oil is carried to Seattle in tanks aboard the steamers. The East Water Way Dock, built during the war to handle shipments of imported Oriental oils, now handles fish oil and fish from the Pacific Coast. It is one of the finest docks in the United States for handling oil and meal. From storage tanks on the docks the oil is pumped into tank cars that carry it to the consumer. Prior to shipment representative samples of the oil and meal are tested and the products are sold upon the results of these tests.

Some herring oil is shipped to the East in tank car quantities; however it is estimated that from 85 to 90% of the production is used on the coast. The meal is consumed on the Pacific Coast for feeding and fertilizing purposes and about two thousand tons are exported to Japan.

### Salmon Oil

In the important salmon canning industry on the Pacific Coast, a large portion of the waste fish is discarded in certain localities. It is dumped overboard because it has

*Forty thousand British Columbia salmon just unloaded into receiving chutes of a large cannery*

not been economically possible to utilize it. If it were manufactured into salmon oil and meal, production in Washington, British Columbia and Alaska would be quadrupled. Domestic production at the present time is only two hundred thousand gallons annually.

The salmon reduction industry is carried on as an adjunct to the salmon canneries, and in three or four places as a separate industry. At Ketchikan, Alaska, for example, a company collects the offal from the ten canneries there. At several large canneries small by-products plants have been installed to save the waste.

The wet rendering system is employed in connection with handling the waste from an individual salmon cannery. These plants are of the continuous type but are adapted to handle salmon. The heads and backbone, left from the canning process, are crushed and thoroughly cooked. Salmon offal requires considerably more cooking than herring in order to release the oil cells. It was not until 1923 that plants of this type were used.

The central rendering plants generally use the batch system, with either wet or dry rendering. At the present time I believe there are only three plants operating, although there were five at one time on Puget Sound alone.

Salmon oil is used for tanning leather, in the manufacture of paints and soap. When properly manufactured it is considered a

high grade fish oil. Some salmon oil averages less than one per cent free fatty acid, but the free fatty acid content of the oil will vary with each plant according to the individual process used.

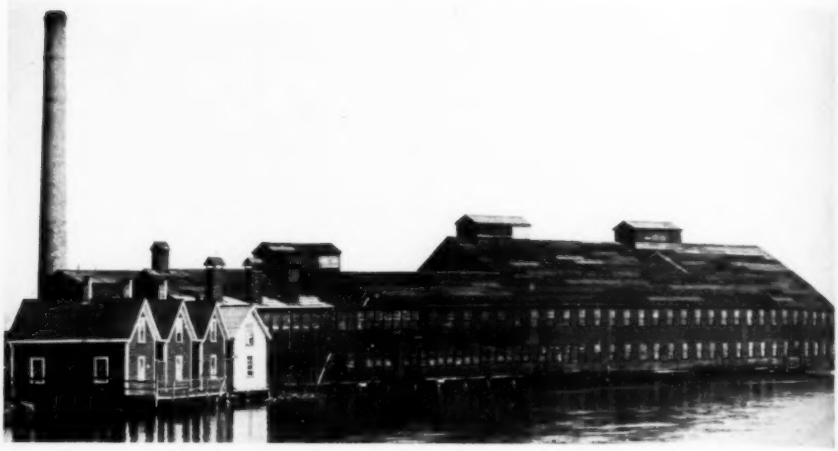
### Solvent Process

The solvent process is relatively unimportant but has possibilities. It has been used in the past in California and in Washington but the plants have been closed due to inefficient operation. They have also had trouble with obtaining standard solvents. Some of the plants used gasoline and attribute their failure to the lack of good grades of gasoline. Their products were also very poor in comparison to the products produced by the other systems, for example, the oil was very dark and sometimes contained some of the solvent. It should have been filtered by the use of infusorial earth or some similar filter aid. If these companies had conducted research they would probably have been successful since this type of plant is used in several of the European countries and has proven very profitable. Its use should become more general in the future provided adequate research is conducted prior to installation of the plants.

### Governmental Co-operation

Scientific research has been the means of bringing about a large number of improvements in fishing methods; preservation of the fish by refrigeration in the menhaden industry; rendering methods; refining methods; and hardening of the oils. The Bureau of Fisheries have a sum of $30,000 in the deficiency bill which they hope passes Congress this winter so that it may be used for securing additional men for research. One of their greatest problems is to work out a method that will economically handle small quantities of fish waste. The Bureau is studying methods to prolong the life of the

*A good haul—lifting seine with menhaden*



*One of the largest herring canneries on the Maine coast, has packed as much as 300,000 cans of herring daily*

fishing gear by the use of new net preservatives; studying the life history of the fish so they may know more about its habits, and can maintain a permanent supply.

The individual States, in which the fishing is prosecuted, have control over their respective fisheries while the Federal government has control of Alaskan fisheries and of inter-

*Over one thousand trolling boats in Neah Bay, Washington, farthest point north in the United States*

state shipments of meal and oil. In Alaska the Bureau has limited the herring fishing season from June to October, and also has specified a closed season from Saturday evening until Monday morning. When someone develops a small machine that will handle the waste from the salmon canneries the salmon canners will be enabled to save two million dollars' worth of salmon offal that is now dumped overboard.

The United States Tariff Commission makes two distinctly different kinds of investigations:

(1) They make formal investigations on various subjects under the tariff act of 1922, as requested by the interested parties. These include a study of domestic and foreign situations, including production, imports, exports, uses, cost of production and the competitive situation. Under this act the Presiden has the power to raise or lower the tariff after an investigation by the Tariff Commission.

(2) The second function of the commission is to prepare surveys on the various articles included in the tariff act. These reports are generally printed for use by the trade and for congress. For example, the writer is now preparing one, "Fish and Marine Animal Oils." These reports can be secured by writing the Tariff Commission.

The studies made under the act of 1922 and the regular surveys include the advantages and disadvantages of the foreign and domestic situations as well as statistical data.

### Future of the Industry

The future of the industry depends upon—

(1)—The conservation and preservation of the supply;

(2)—Greater efficiency in reduction plants which will decrease the cost of production;

(3)—Better methods of producing and refining the oil;

(4)—Increased use of the oil for edible purposes and new uses of the oil for inedible purposes;

It has only been during the last five years that the consumption of fish oils in the United States has increased substantially. At the present time it looks as though fish oils will be more prominent in the future than they have been in the past.

OIL CHEMISTS

*Make your hotel reservations early for the A. O. C. S. Convention*

New Orleans, La., May 14 and 15, 1928

# The Standardization of Cod Liver Oil

## Further Suggestions on the Use of the Uranium Nitrate Color Test

BY WALLACE H. DICKHART

IN last September's edition of this journal the writer published an article on the behavior of fish oils with uranium nitrate and pyrogallic acid. At that time a method[1] was proposed to differentiate between cod liver oil (U. S. P.) and contaminated cod liver oil. Since then a slight modification of the test has been suggested by a prominent chemist who found it more convenient to heat the test tube containing the oil and reagent by letting it stand in a 400 cc beaker with about 80 cc of water and heating so that the water just boils; instead of placing the tube in a steam bath as published.

### Modification

Modifying the test so that the following data could be assembled 10 milligrams of uranium nitrate and 3 cc of the oil to be tested were placed in a 6 inch glass tube with an inside diameter of 20 mm. The tube was then placed upright in a 400 cc beaker containing 80 cc of water which was heated, so that it just boiled, keeping this temperature for 20 minutes, after which the oil was allowed to cool and the color measured. Failure to pay attention to these details will without doubt result in condemning good oils. The method, if carefully conducted, I believe will have a value as a rapid sorting test to separate good oils from those contaminated with oils other than those from the livers of fish related to the cod.

### Green Color

Further investigations indicate that certain grades of sardine oil such as Northern California give a deep green color like that of chlorophyll in 2 minutes with the uranium nitrate, at boiling water temperature gradually changing to red on further heating. The characteristics of the California sardine oil are Sp. Gr. @ 15.5° C 0.9319, Iodine Value 186.7, Saponification value 190.2, Unsaponifiable matter 0 54%, Free Fatty Acid 1.50%, Index of refraction @ 40° C 1.4747, Cold Test 36° F.

Hake liver and dogfish liver oils will also give a decided green color which on further heating changes to a dark amber or reddish brown color.

### Color Reading Experiments

Experiments and analysis were conducted to prove that the fish oil actually changed to give a definite color reading with the uranium nitrate. Samples were collected and analyzed according to the United States Pharmacopoeia method. The color of the oil was read, before and after heating with uranium nitrate, in a Wesson tintometer[2] using standard Lovibond

[1] Ten milligrams of uranium nitrate plus 3 cc. of fish oil placed in a test tube and heated in a steam bath for 20 minutes.

[2] As adopted by the American Oil Chemists Society.

glasses. Samples of pure cod liver oil were tested for unsaponifiable matter and the uranium nitrate test with the following results.

| Cod Liver Oil | Before Heating | After Heating | Unsapon. |
|---|---|---|---|
| U. S. P. oil..... | 1 yellow 0.1 red | 35 yellow 3.8 red | 1.20% |
| U. S. P. oil..... | 1 yellow 0.1 red | 35 yellow 3.7 red | 1.19% |
| U. S. P. oil..... | 1 yellow 0.1 red | 35 yellow 3.8 red | 1.20% |
| Poultry grade oil... | 1.5 yellow 0.2 red | 35 yellow 5.3 red | 1.46% |
| A refined[3] oil..... | 5 yellow 0.3 red | 35 yellow 5.0 red | 4.15% |

[3] The oil was too dark to be read, so it was first refined with sodium hydrate.

The above poultry grade of cod liver oil was unsatisfactory for a medicinal oil and gave the following characteristics, Sp. Gr. @ 15.5° C 0.9309, Iodine Value, 161.8, Saponification Value 185.5, Unsaponifiable matter 1.46%, Index of Refraction 1.4726 @ 40° C, Free Fatty Acid 0.30% and Cold Test 16° F.

## Experimental

A cod liver oil (U. S. P.) containing 5% of California sardine oil was analyzed and the analysis compared thus:

| | U. S. P. Cod Liver Oil | 5% Mixture | California Sardine Oil |
|---|---|---|---|
| Specific Gravity 15.5° C. ..... | 0.9235 | 0.9264 | 0.9319 |
| Iodine value ..... | 162.6 | 163.8 | 186.7 |
| Saponifiable value ..... | 180.5 | 188.1 | 190.2 |
| Unsaponifiable ..... | 1.20% | 1.16% | 0.54% |
| Free fatty acid..... | 0.60% | 0.60% | 0.50% |
| Refraction index @ 40 C. .... | 1.4728 | 1.4729 | 1.4747 |
| Cold test liquid..... | 0° F. | 8° F. | 36° F. |
| | Color Reading | | |
| Before heating ..... | 1 Y. 0.1 R. | 2 Y. 0.5 R. | 35 Y. 1.2 R. |
| After heating ..... | 35 Y. 3.8 R. | 35 Y. 4.9 R. | 35 Y. 5.0 R. |

Other mixtures were made using the same cod liver oil with sardine oil having an unsaponifiable matter of 1.08%. The samples were tested for color readings together with Whale, Menhaden, Pilchard, Dogfish, Seal, and Herring oils and the data tabulated.

| | Color Before Heating | Color After Heating |
|---|---|---|
| Cod Liver (U. S. P.) oil..... | 1 yellow 0.1 red | 35 yellow 3.8 red |
| 1% Sardine in cod..... | 1 yellow 0.1 red | 35 yellow 4.0 red |
| 5% Sardine in ocd..... | 1 yellow 0.2 red | 35 yellow 5.2 red |
| 10% Sardine in cod..... | 1.5 yellow 0.3 red | 35 yellow 6.0 red |
| Seal oil (unsaponifiable 0.41%)..... | 1 yellow 0.2 red | 35 yellow 4.0 red |
| Sardine oil (unsaponifiable 1.08%)... | 35 yellow 3.5 red | 35 yellow 6.0 red |
| Whale oil (unsaponifiable 1.50%).... | 35 yellow 3.3 red | 35 yellow 9.7 red |
| Menhaden oil (unsaponifiable 1,23%). | 35 yellow 4.1 red | 35 yellow 12.0 red |
| Pilchard oil (unsaponifiable 0.96%)... | 35 yellow 3.7 red | 35 yellow 10.0 red |
| Herring oil (unsaponifiable 1.00%)... | 35 yellow 4.5 red | 35 yellow 15.0 red |
| Dogfish oil (unsaponifiable 10.18%)... | 35 yellow 4.7 red | 35 yellow 27.6 red |

## COMMERCIAL COD LIVER OIL

Samples of commercial cod liver oil were analyzed and the colors compared in the following manner:

| Sp. Gr. @ 15.5° C. | Iodine Val. | Sapon. Val. | F. F. A. | Un-sapon. | Index Ref. @ 40° C. | Color | |
|---|---|---|---|---|---|---|---|
| | | | | | | Before Heating | After Heating |
| 0.9202 | 134.9 | 177.2 | 3.00% | 5.52% | 1.4695 | 5 y–1.0 r | 35 y–11.6 r |
| 0.9240 | 151.8 | 178.8 | 3.50% | 4.58% | 1.4725 | 5 y–1.3 r | 35 y–11.2 r |
| 0.9250 | 154.7 | 183.7 | 4.00% | 3.15% | 1.4719 | 5 y–0.5 r | 35 y– 7.7 r |
| 0.9225 | 144.8 | 187.3 | 4.10% | 3.12% | 1.4697 | 5 y–2.1 r | 35 y–12.0 r |
| 0.9238 | 152.9 | 181.5 | 4.55% | 2.70% | 1.4610 | 5 y–1.0 r | 35 y– 8.1 r |
| 0.9214 | 145.2 | 183.5 | 3.05% | 4.16% | 1.4700 | 5 y–1.0 r | 35 y– 7.7 r |
| 0.9229 | 152.0 | 188.0 | 4.25% | 2.75% | 1.4690 | 5 y–1.0 r | 35 y– 8.2 r |
| 0.9198 | 144.2 | 178.8 | 4.19% | 8.73% | 1.4695 | 5 y–2.7 r | 35 y–28.5 r |
| 0.9250 | 153.0 | 180.9 | 3.99% | 3.72% | 1.4724 | 5 y–2.1 r | 35 y–14.1 r |
| 0.9210 | 135.6 | 182.0 | 16.40% | 1.47% | 1.4672 | 35 y–1.9 r | 35 y– 9.8 r |

## COLD PRESSED HERRING OIL

Comparing characteristics of the Herring, Sardine, Whale, Dogfish and Cod Liver Oils we have the following:

| | Herring Oil | Sardine Oil | Dogfish Oil | Whale* Oil | Poultry Cod Liver Oil |
|---|---|---|---|---|---|
| Specific gravity @ 15. 5° C..... | 0.9219 | 0.9319 | 0.9175 | 0.9257 | 0 9319 |
| Iodine value ..... | 135.7 | 186.7 | 133.2 | 136.0 | 161.8 |
| Sapon. value ..... | 189.7 | 190.2 | 166.3 | 183.3 | 185.5 |
| Unsaponifiable ..... | 1.63% | 0.54% | 10.18% | ..... | 1.46% |
| Free fatty acids..... | 6.60% | 1.50% | 2.20% | 0.18% | 0.30% |
| Cold test ..... | 26° F. | 36° F. | 14° F. | ..... | 16° F. |
| Color before heating..... | 35 y 5.3 r | 35 y 1.2 r | 35 y 4.7 r | ..... | 1.5 y 0.2 r |
| Color after heating..... | 35 y 13.0 r | 35 y 5.0 r | 35 y 27.6 r | ..... | 35 y 5.3 r |
| Index refraction @ 40° C..... | 1.4689 | 1.4747 | 1.4698 | ..... | 1.4726 |

* Antarctic Right Whale (America) Lewkowitsch, sixth edition (vol. 11), page 470.

Comparing the values of the commercial cod liver oils we find but one that passes the U. S. Pharmacopoeia for unsaponifiable matter, and that gives characteristics similar to that of Whale Oil, and yet these are all Cod Liver Oils. Therefore, I would suggest, from the experiments that have been made above: ("A") that for medicinal cod liver oil a maximum of 1 yellow 0.1 red before heating with uranium nitrate and 35 yellow 3.8 red after heating be allowed on a basis of approximately 10 mm x 20 mm column of oil, (which equals 3 cc of oil); ("B") that for poultry oil 1.5 yellow 0.2 red in the cold and 35 yellow 5.0 red after heating be the established standard in the uranium nitrate test conducted as described above.

# The Chemical Composition of Ergot Oil

BY WALTER F. BAUGHMAN AND GEORGE S. JAMIESON*

ERGOT is the dried sclerotium of *Claviceps pur purea* (Tulasne) developed on rye plants. The same fungus, or one closely related, grows on a number of other grasses. It was the original source of ergosterol (Tanret Ann. Chim. Phys. (6), *20*, 289 (1890); ibid (8), *15*, 313 (1908)), but this sterol has now been identified in a wide range of lower plants, for example, certain yeasts and in a number of animal and vegetable fatty oils. Rosenheim and Webster (Biochem. Jour. *21*, 389 (1927)) also Windaus and Hess (Nachr. Ges. Wiss. Göttingen, 1927, 175) have advanced the opinion that ergosterol or a highly unsaturated sterol of similar constitution is the natural parent substance of antirachitic vitamin D, and is converted into vitamin D by irradiation with ultra-violet light.

Ergot contains a fatty oil which it is necessary to extract with petroleum ether before preparing the fluid extract used in medicine (U. S. Pharmacopœia X, pp. 133, 167). This oil has been the subject of investigations at different times for many years, Wiggers (Annalen *1*, 129 (1832) as early as 1832 reported that ergot contained 35 per cent of fatty oil. Herrmann, (Jahresber, Pharm. 1869), Ludwig (ibid 1869, 25) and Gauser (ibid 1871, 13) made short communications concerning the oil. Most of the investigators have found that the oil gives a high acetyl number and have described it as containing hydroxyoleic acid. Mjöen (Arch. Pharm. 234, 278 (1896)) gave 62.9 as the acetyl number, and stated that he found the oil to contain glycerides of palmitic acid, oleic acid, and a hydroxy tatty acid which he had not succeeded in isolating. Rathje (Arch. Pharm., *246*, 696 (1908)) reported the acetyl number as 27.4, and the percentage composition as follows: oleic acid, 68 per cent; hydroxyoleic acid, 22 per cent; and palmitic acid, 5 per cent. The composition obtained by Dieterle, Diester and Thimann (Archiv. Pharm., *265*, 171 (1927)) as a result of their elaborate investigation was: palmitic, daturic, and other saturated acids, 20.5 per cent; ω-linolic acid, 4.6 per cent; and oleic acid, 71.0 per cent. They could not prove the presence of hydroxy fatty acid. The oil used by them gave an acetyl number of 60.4, but the insoluble fatty acids prepared from this oil gave an acetyl number of only 20.6, and they expressed the opinion that the high acetyl number of the oil may have been caused by the presence of mono- and diglycerides. Finally, Matthes and Schütz (Arch. Pharm., *265*, 541 (1927)) claim to have isolated hydroxyoleic acid and dibromide from the bromides of the liquid acids by treatment with petroleum ether at low temperature and to have obtained pure hydroxyoleic acid by reducing this dibromide with zinc.

The authors recently received a two-liter sample of ergot oil from the Drug Control Laboratory, Food,

*Oil, Fat and Wax Laboratory, U. S. Department of Agriculture.

Drug and Insecticide Administration, Department of Agriculture, and on account of the meager knowledge regarding the composition of the oil available in the literature it was thought worth while to make a rather extensive examination of it. The oil had been extracted in the Drug Laboratory with petroleum ether from a composite sample of Russian, Spanish, and Austrian ergot. This composite sample of ergot contained 5.50 per cent moisture and 32.75 per cent oil, which is equivalent to 34.66 per cent (dry basis) oil. This sample of oil was dark red by transmitted light, but by reflected light there was a dark brownish yellow fluorescence. However, other samples of ergot oil have been seen which had a light yellow color. At room temperature the oil was viscous but less so than castor oil. After standing in the ice box (10°-12° C.) for a month it became more viscous of course, but did not deposit any stearin.

*Chemical and Physical Characteristics.* — The more important characteristics were determined, and the results are reported in Table I. The iodine number indicates that it is a non-drying oil, and the very low Reichert-Meissl and Polenske numbers show that glycerides of volatile acids are absent. The acetyl value is low and indicates that hydroxylated acid is not present in an appreciable quantity. A second sample of oil extracted from a different lot of ergot gave an acetyl value of 11.0. The percentages of saturated and unsaturated fatty acids were determined by the lead salt-ether method, and corrections were made for the small quantity of unsaturated acids that separates with the saturated acids fraction as indicated by the iodine number of the saturated acids fraction (J. A. C. S. *42*, 2398 (1920); Cotton Oil Press *6*, No. 1, 41 (1922) ) and it was also taken into account that the unsaponifiable matter separates with the unsaturated acids fraction, in this determination.

TABLE I

Ergot Oil

Chemical and Physical Characteristics

| | |
|---|---|
| Specific gravity 25°/25° | 0.9222 |
| Refractive index, 25° | 1.4691 |
| Acid value | 3.02 |
| Iodine number (Hanus) | 73.8 |
| Saponification value | 196.9 |
| Unsaponifiable matter (%) | 1.18 |
| Acetyl value | 7.3 |
| Reichert-Meissl number | 0.3 |
| Polenske number | 0.4 |
| Saturated acids as determined (%) | 27.2* |
| Unsaturated acids plus unsaponifiable matter as determined (%) | 68.6 |
| Iodine number of unsaturated acids | 101.2 |
| Saturated acids (corrected) (%) | 26.5 |
| Unsaturated acids (corrected) (%) | 68.1 |

*Iodine number, 2.6

*Unsaturated Acids.*—The iodine number of the unsaturated acids fraction (101.2) lies between the theoretical iodine numbers of oleic acid (90.1) and linolic acid (181.4). The saponification value, as determined, of the unsaturated acids fraction containing the unsaponifiable matter is 193.8. Making allowance for the unsaponifiable matter the saponification value of the unsaturated acids becomes 197.2. This figure is close to the theoretical values for oleic acid (198.65) and linolic acid (200.1). These data indicate that this fraction of the fatty acids consists of oleic and linolic acids. The following percentages were calculated from the foregoing iodine numbers.

| | Per cent | In original oil Per cent | Glycerides in original oil Per cent |
|---|---|---|---|
| Oleic acid ..... | 87.84 | 59.8 | 62.5 |
| Linolic acid ..... | 12.16 | 8.3 | 8.7 |
| | 100.00 | 68.1 | 71.2 |

*Saturated Acids.*—A quantity of saturated acids, prepared by the lead salt-ether method, was esterified with methyl alcohol (J. A. C. S. *42*, 1200 (1920) ). The mixture of methyl esters, which weighed 118 g., was fractionally distilled under diminished pressure. The data for this distillation are given in Table II. A preliminary distillation from a 1-liter Claissen flask resulted in six fractions designated by the letters A to F, and a residue. These preliminary fractions were redistilled from a 250 cc. Ladenburg flask as indicated in the table, and seven fractions and a residue were obtained.

The iodine numbers, which are measures of the contaminating unsaturated acids, and the saponification values of the final fractions were determined, Columns 2 and 3 of Table III give the results. From these data the mean molecular weights of the saturated acid esters in each fraction were calculated; the results are recorded in Column, 6, Table III (J. A. C. S., *42*, 152, 1197 (1920) ). The results in Column 6 indicate what saturated acid esters may be present in the various fractions. The result for Fraction 1 lies between the molecular weights of methyl myristate (242.3) and methyl palmitate (270.3) and suggests therefore the presence of these two esters. The indicated constituents for Fractions 2 to 6 are methyl palmitate and methyl stearate (298.4), and for Fraction 7, methyl stearate and methyl arachidate (326.4).

The free acids were recovered from some of these fractions, and the constituent saturated acids were isolated by fractional crystallization from alcohol. Their identities were established by their melting points and by observing whether or not these melting points were lowered when the substances were mixed with equal quantities of the respective acids which they were suspected of being, the purity of which had been established previously by elementary anaylsis. In all cases the melting points of the isolated acids confirmed the deductions drawn from the mean

molecular weights of the fractions.

Pure myristic acid was isolated from Fraction 1; pure palmitic acid was obtained from Fractions 1 and 3; stearic acid, from Fractions 2 and 3; and arachidic acid, from Fraction 7 and from the final residue. This residue, however, was composed mostly of decomposition products and was not taken into account in calculating the quantities of saturated acids.

The quantities in the various fractions were calculated from the mean molecular weights of the saturated acid esters (Col. 6, Table III), and the theoretical molecular weights of the two esters in each fraction. The results are given in Columns 7-14, Table III. The saturated acids data are summed up in Table IV, and the equivalent percentages of glycerides in the original oil are given in Column 4.

TABLE II

Ergot Oil

Fractional Distillation of Methyl Esters of Saturated Acids

(118 g. subjected to distillation.) Distillation at 8 mm. pressure

| | Fraction | Temperature °C. | Weight g. |
|---|---|---|---|
| | A | 183–5 | 19.9 |
| | B | 185 | 21.6 |
| | C | 186–7 | 22.8 |
| | D | 187–8 | 22.4 |
| | E | 188–198 | 21.1 |
| | F | 198-218 | 6.1 |
| | Residue | | 4.1 |
| Fractions A and B redistilled..... | 1 | 183–4 | 6.8 |
| | 2 | 185–7 | 23.0 |
| Fractions C and D added..... | 3 | 188 | 23.7 |
| | 4 | 188 | 23.5 |
| Fraction E added ..... | 5 | 190–5 | 22.0 |
| Fraction F and residue added..... | 6 | 197–207 | 12.4 |
| | 7 | 207–225 | 6.2 |
| | Residue | | 0.4 |

TABLE III

Ergot Oil

Results of Analyses of Fractions Obtained by Distilling Methyl Esters of Saturated Acids

| Fraction | Iodine Number | Saponification Value | Mean Molecular Weight | Esters of Unsaturated Acids, % | Molecular Weight of Esters of Saturated Acid | Myristic Acid | | Palmitic Acid | | Stearic Acid | | Arachidic Acid | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | % | g. | % | g. | % | g. | % | g. |
| 1 | 1.2 | 211.3 | 265.5 | 1.24 | 265.1 | 17.28 | 1.18 | 76.25 | 5.18 | .... | .... | .... | .... |
| 2 | 0.7 | 206.9 | 271.1 | 0.73 | 271.0 | .... | ... | 91.79 | 21.11 | 2.35 | 0.54 | .... | .... |
| 3 | 1.3 | 205.5 | 273.0 | 1.35 | 272.9 | .... | ... | 84.88 | 20.12 | 8.70 | 2.06 | .... | .... |
| 4 | 1.3 | 204.9 | 273.8 | 1.35 | 273.5 | .... | ... | 82.88 | 19.48 | 10.71 | 2.52 | .... | .... |
| 5 | 3.6 | 201.3 | 278.7 | 3.73 | 278.1 | .... | ... | 65.95 | 14.51 | 25.47 | 5.60 | .... | .... |
| 6 | 6.9 | 193.4 | 290.1 | 7.16 | 289.6 | .... | ... | 27.57 | 3.42 | 60.77 | 7.54 | .... | .... |
| 7 | 12.6 | 180.7 | 310.5 | 13.07 | 312.9 | .... | ... | .... | .... | 39.94 | 2.48 | 43.09 | 2.67 |
| | .... | ..... | ..... | .... | .... | .... | 1.18 | .... | 83.82 | .... | 20.74 | .... | 2.67 |

TABLE IV

Ergot Oil—Saturated Acids

| Acid | Acids in saturated acid fraction | | Acids in original oil | Glycerides in original oil |
|---|---|---|---|---|
| | Grams | Per cent | Per cent | Per cent |
| Myristic | 1.18 | 1.09 | 0.29 | 0.3 |
| Palmitic | 83.82 | 77.32 | 20.49 | 21.5 |
| Stearic | 20.74 | 19.13 | 5.07 | 5.3 |
| Arachidic | 2.67 | 2.46 | 0.65 | 0.7 |
| | 108.41 | 100.00 | 26.50 | 27.8 |

*Summary*

The chemical composition of ergot oil has been determined with the results given below:

| | | Per cent |
|---|---|---|
| Glycerides of | Oleic acid | 62.5 |
| | Linolic acid | 8.7 |
| | Myristic acid | 0.3 |
| | Palmitic acid | 21.5 |
| | Stearic acid | 5.3 |
| | Arachidic acid | 0.7 |
| Unsaponifiable matter | | 1.2 |

It was not possible to detect in this oil either daturic acid or hydroxylated acid, which have been reported as present by other investigators.

# Book Reviews

## Fats and Oils Studies of the Food Research Institute

THE FOOD RESEARCH INSTITUTE of Stanford University, California, announces its second series of investigations in commodity economics—the *Fats and Oils Studies*.

The whole subject of fats and oils is of large and increasing importance. Origins and uses are strikingly diverse, and the various fats and oils are technically interchangeable to a remarkable degree. Marked changes have occurred and are still occurring in production, manufacture, consumption, international trade, and price relationships. Partly as a result of these changes, broad questions of public policy have arisen, especially with respect to agriculture, food laws, and tariffs. The fats and oils constitute a field peculiarly adapted to organized research by a group like the Food Research Institute, equipped to handle technological as well as economic and statistical problems.

For the present, *Fats and Oils Studies* will be published as books and pamphlets of varying length, identical in format. Ordinary studies will cover 100-200 large octavo pages, and will be sold at prices of $1.00, $1.50, and $2.00. Each study will constitute an adequate consideration of a selected topic, but necessary interdependence of studies makes for a homo-

geneous series. The high standards of research embodied in *Wheat Studies of the Food Research Institute* will be maintained in the new series dealing with fats and oils. The following studies are now in press or near completion, and will appear in the designated order:

No. 1. *The Fats and Oils: A General View*

No. 2. *Copra and Coconut Oil*

No. 3. *Inedible Animal Fats*

No. 4. *The McNary-Haugen Plan as Applied to Corn and Hogs*

No. 5. *History of the Lard-Compound Industry*

Detailed descriptions of these and subsequent investigations will be available as the studies are ready for distribution. Announcements of each of the *Fats and Oils Studies of the Food Research Institute* will be sent to individuals or organizations who request them.

STANFORD UNIVERSITY, California
February 1, 1928

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EDITOR'S NOTE: The Studies announced above should be of the greatest interest to all readers of OIL & FAT INDUSTRIES. We suggest that you write promptly to reserve Your copy of each Study.

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A SHORT HAND-BOOK OF OIL ANALYSIS. By Augustus H. Gill, Sc.D. 11th Edition, Revised and Enlarged. Pp. 287. Philadelphia: J. B. Lippincott Co.

Commercial and manufacturing laboratories in which oils and greases are tested, as well as teachers and students of oil analysis, will heartily welcome this new edition of an old friend. While its original function of a laboratory manual for quick reference in routine testing work has been strictly adhered to, the subject matter has been developed and extended to keep pace with the advance of knowledge of the analysis and inspection of the mineral and fatty oils.

Two new chapters have been added to this edition—one, a brief statement of the composition of different oils; the other, the methods of examination of Motor Gasoline and Fuel Oil. The special tests, methods of analysis and the description of the special oils and greases have been revised where necessary to bring the book thoroughly up to date.

It is to be regretted that the Wijs iodine number method has not been given in full except in the appendix (being subordinated to the Hanus method in the book), as the former method is more favored at the present time by a majority of the prominent oil analysts.

This handbook continues to hold its place among the primarily essential reference works for oil chemists, and for teachers and students of oil analysis.

ALAN PORTER LEE

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## Apologies to Mr. Dunning

Through an oversight in the Secretary's office, the new list of members of the Society which was recently printed and mailed out to the Membership, omitted the name of Mr. G. R. Dunning, Box 2406, Amarillo, Texas. Mr. Dunning has been a member of the American Oil Chemists' Society in good standing for several years, and the Secretary desires to correct hereby the unintentional omission of Mr. Dunning's name from the list referred to. The remaining copies in the Secretary's office have been corrected by the addition of Mr. Dunning's name and address.

# The American Oil Chemists' Society

**Notes and Correspondence**

## President's Call for Annual Meeting

Dear Fellow Members:

Our annual meeting will be held May 14th and 15th at the Hotel Roosevelt, New Orleans, and it is very desirable that every member should try to be present.

It is essential that the chairmen of all the committees have their reports in the hands of the Uniform Methods Committee not later than April 1st, in order that they can be considered and proper recommendations made on them at our annual meeting. The Chairman of this committee is N. C. Hamner, c/o Southwestern Laboratories, Dallas, Texas. Will you also send copies of your report to H. J. Morrison, Chairman of the Planning Committee, c/o Procter & Gamble Company, Ivorydale, Ohio, and to the President at No. 2 Broadway, New York City?

Hoping to see you all there, I am,

Very truly yours

H. P. TREVITHICK,
PRESIDENT.

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To The Editor,
Oil & Fat Industries,
New York, N. Y.
Sir:

Referring to Mr. Priest's article published in the Journal this month, regarding tests on the sensitivity of certain of our members to color. Mr. Priest informs me that any one, who desires, can be examined at the Bureau of Standards at any time, provided arrangements are made direct with Mr. Priest.

These examinations will be made under the best possible conditions, and will definitely establish whether the member is color blind or not. Mr. Priest has stated in his article, that each man who was tested at Memphis will be given his own number, so that he may ascertain what his own results were. The key to these numbers is in Mr. Priest's possession, and will not be disclosed. However, the Referee Board will probably require that persons applying for a referee certificate, will either have to pass this test, or have it passed by some one in their employ, in order that the Board will know that each Referee laboratory has some one capable of reading colors correctly. If it seems desirable, Mr. Priest will again arrange to have tests made at the New Orleans meeting for those who would prefer to have it done at that place.

If I remember correctly, the Society was willing at the last meeting that the results of the tests at Memphis should be given to the Referee Board, but it would seem fairer that those men who did not have as good a reading as the others be given another test under more favorable conditions. Those who passed the test at Memphis, of course, can stand on the results of these tests, if they choose. Will those who wish to have the test made at New Orleans, please write me or Mr. Priest, in order that he can decide whether to bring the apparatus with him?

Very truly yours

H. P. TREVITHICK,
PRESIDENT.

# Standardization of Lovibond Glasses

## Report for January, 1928

*I. Tests of Sixty-five 35-Y Glasses Submitted by A.O.C.S., August, 1927.*

The chief activity this month has been the examination and intercomparison of sixty-five Lovibond 35-Y glasses submitted by Mr. Trevithick in August, 1927. At the same time, and a few weeks later, there were submitted 129 red glasses. A few observations were made by Judd in August to determine the red correction of the yellow glasses. They were then put aside and all work was concentrated on two tasks, viz: (1) the calibration of the red glasses; and (2) the task of selecting (from the set B. S. 9940) red glasses of exact integral values and exact fractions by steps of 0.10. The first of these tasks having been disposed of (see published report, Oil and Fat Industries, p. 16, January, 1928) and the second being well advanced, we have now returned to the examination of this large group of 35-Y glasses.

The temporary paper labels bearing the A.O.C.S. identification numbers have been replaced by engraved marks, and a detailed inventory of the glasses has been prepared showing all marks engraved on them and noting scratches, pits, striae, haze and other blemishes. The following data have been obtained on these 35-Y glasses;

(1) The "red correction" (that is the Lovibond red required to be combined with each of these glasses to match a constant comparison 35-Y, or required to be combined with the constant comparison 35-Y to match the glass being tested) has been determined for each of these glasses by each of two observers, with results which agree to within 0.05R except in twelve cases which are now being reviewed. The range of the "red correction" for this group of sixty-five 35-Y glasses appears to be about 0.3R (or perhaps 0.4); that is to say, the two extreme glasses in this lot differ by about this amount of red. The overall range of the "red correction," considering all 35-Y glasses which we have ever observed, appears to be about 0.5 or 0.6R. (Judd and Walker).

(2) The transmission of each of the glasses has been determined at each of the following wavelengths:—480, 510, 550, 610 millimicrons. In making these measurements temperature is taken into account and the results reduced to 25°C. (Gibson and Brown).

(3) The white light transmission of each of these glasses has been measured relative to a comparison standard 35-Y (B.S. 10-289B) by means of the Martens photometer. (Judd).

(4) The dominant wavelengths are being measured by direct comparison with the dominant wavelength of 35-Y (B.S. Test 41960). Observations on 42 out of the lot of 65 were completed at the end of the month. These data will form a check on the red corrections obtained by Judd and Walker. (Priest).

Besides obtaining the above mentioned experimental data, the following computations have been carried through for each of these 65 glasses:—

(1) The Lovibond numeral on the additive scale of Priest and Gibson (established April-May, 1927) has been computed by means of the empiric formula

(Numeral = $-37\log_{10}\left[\frac{T_{480}}{T_{550}}\right]$ where $T_{480}$ and $T_{550}$ are respectively the transmissions for wavelengths 480 and 550 millimicrons.) derived by Priest last summer. (Gibson and Brown).

(2) The sunlight transmission has been computed from the transmissions for wavelengths 510, 550, and 610 millimicrons by means of the empiric formula derived by Priest last summer. (Gibson and Brown). These transmissions are being compared with transmissions measured by Judd relative to a comparison standard 35-Y (B.S. 10289B). Some large discrepancies which appear between the two sets of transmissions are accounted for by the numerous scratches and pits on the glasses. The propriety of continuing the use of these badly damaged glasses in questionable.

*II. Establishment of Transmission Standards for 35-Y Glasses.*

Extensive measurements by flicker photometry have been made by about 15 observers (with the cooperation of the Photometric Section, Electrical Division) to determine the transmission of a working standard 35-Y (property of the A.O.C.S. and designated as B.S. Test 41960) for sunlight (and also for the light from a lamp at color temperature 2077°K, i.e., a carbon filament lamp operating at 4 watts per candle). As a result of these extensive measurements the sunlight transmission previously computed from the spectral transmission and published in B. S. Sci. Paper No. 547, Table 6, has been verified to within an uncertainty less than 1 per cent. The adopted sunlight transmission for this glass is 0.632. The transmission for light from the carbon filament lamp is 0.667. The use of this glass as a working standard will greatly expedite the measurement of the transmission of glasses to be tested. (Priest, Judd, and Others).

The ratio of the sunlight transmissions of two 35-Y glasses (B.S. 10289B and B.S. Test 41960) has been determined as the result of extensive measurements by means of the Martens photometer. (Judd).

*III. Further Calibration of the Bureau's Red Glasses.*

Calibration of the Bureau's set of Lovibond red glasses has progressed as follows:

(1) The spectral transmission of the following glasses (designated by maker's numbers) has been determined:

1.8, 5.6, 0.13, 0.58, 0.86, 4.8, 8.2, 4.9, 4.6, 7.2, 5.8. (Walker and Gibson).

(2) The search for glasses having exact tenths and exact-integers on the additive scale of Priest and Gibson has been continued on the basis of the just mentioned determinations of spectral transmission. This has resulted in adding the following better approximations to the list given in the report for December, 1927:—

| Desired Numeral | Maker's Mark | Computed Numeral | Computed Numeral minus Desired Numeral |
|---|---|---|---|
| 0.200 | 0.13 | 0.199 | —0.001 |
| 1.000 | 0.86 | 1.003 | + .003 |
| 5.00 | 4.9 | 5.08 | + .08 |
| 8.00 | 8.2 | 8.04 | + .04 |

(Gibson)

(3) Including all previous work, seventy-five red glasses from the Bureau set (B.S. 9940) have now been calibrated, by means of computation from their spectral transmissions, in terms of the scale of Priest and Gibson. The results to date are as follows:

| Maker's Numeral (engraved by Lovibond) | New Numeral (Priest and Gibson) | Maker's Numeral (engraved by Lovibond) | New Numeral (Priest and Gibson) |
|---|---|---|---|
| .01 | 0.093 | 1.0 | 1.173 |
| .02 | .104 | 1.8 | 1.95 |
| .03 | .122 | 2.0 | 2.30 |
| .04 | .112 | 2.8 | 2.99 |
| .05 | .132 | 3.0 | 3.02 |
| .06 | .148 | 3.8 | 3.94 |
| .07 | .152 | 3.9 | 3.94 |
| .08 | .154 | 4.0 | 4.11 |
| .09 | .156 | 4.6 | 4.78 |
| .10 | .172 | 4.7 | 4.89 |
| .11 | .185 | 4.8 | 4.91 |
| .12 | .167 | 4.9 | 5.08 |
| .13 | .199 | 5.0 | 5.58 |
| .17 | .232 | 5.4 | 5.82 |
| .18 | .296 | 5.6 | 6.16 |
| .19 | .272 | 5.8 | 6.19 |
| .20 | .277 | 6.0 | 6.53 |
| .26 | .361 | 6.8 | 6.85 |
| .28 | .365 | 7.0 | 6.83 |
| .30 | .357 | 7.2 | 7.36 |
| .32 | .454 | 7.6 | 7.59 |
| .38 | .495 | 7.8 | 7.90 |
| .40 | .549 | 8.0 | 8.27 |
| .46 | .593 | 8.2 | 8.04 |
| .50 | .626 | 8.8 | 8.81 |
| .54 | .677 | 9.0 | 9.17 |
| .56 | .711 | 9.8 | 10.00 |
| .58 | .665 | 10.0 | 10.07 |
| .60 | .732 | 11.0 | 10.63 |
| .64 | .806 | 12.0 | 12.17 |
| .70 | .875 | 13.0 | 12.98 |
| .74 | .900 | 14.0 | 13.90 |
| .80 | .879 | 15.0 | 15.47 |
| .84 | .984 | 16.0 | 16.65 |
| .86 | 1.003 | 17.0 | 17.12 |
| .88 | .984 | 18.0 | 18.15 |
| .90 | 1.021 | 19.0 | 18.81 |
| | | 20.0 | 19.67 |

(4) Notable progress has been made in determining (by comparison in the Martens photometer) the relative white light transmissions of nineteen working standard red glasses in combination with 35-Y, but these data are not ready to be reported. (Walker, Judd, Priest).

(5) Preliminary data on spectral transmission obtained in 1920 by Dr. M. Katherine Frehafer are being reviewed and compared with the data of Gibson and Harris (B.S. Sci. Pap. 547), and are being used to make a partial calibration independent of that of Priest and Gibson (April-May 1927). When finished this review and computation will afford a valuable check on the data of Gibson and Harris and the scale derived by Priest and Gibson. (Gibson and Riley).

(6) The rate of change of Lovibond numeral and dominant wavelength for constant 35-Y and variable red has been computed from the O.S.A. data on excitations. The same function has also been derived from experimental data taken by Priest last spring. Study and final tabulation of these data are in course but not yet completed. Some new experimental data have also been taken. The rate of change of hue with Lovibond number has also been studied in a preliminary way. (Priest and Judd).

*IV. Calibration of Red Glasses Submitted by A.O.C.S.*

Calibration of fourteen red glasses submitted by the A.O.C.S. (Through Mr. Putland) January 16, 1928 has been started. (Walker)

*V. Publication.*

The report by Judd and Walker on "A Study of 129 Lovibond Red Glasses with Respect to the Reliability of their Nominal Grades" was published in the January number of OIL AND FAT INDUSTRIES."

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